

COMMONWEALTH



OF AUSTRALIA

Bureau of Meteorology, Melbourne

BULLETIN No. 20, 1934

Zones of Relative Physical Comfort in Australia

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HENRY BARKLEY

Assistant Director

PUBLISHED BY AUTHORITY OF THE MINISTER
FOR THE INTERIOR UNDER THE DIRECTION OF

W. S. WATT,

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Zones of Relative Physical Comfort in Australia.

Man's effective occupation of a territory depends upon the attainment, without undue effort, of a degree of comfort conducive both to health and to a maximum output of energy. Temperature and humidity are the principal factors conditioning human comfort, since the body is maintained in thermostatic equilibrium at a temperature of 98.4°F. , as the result of a balance of heat income developed from food against the loss due to radiation and evaporation or transpiration.

Many criteria have been suggested as the bases for scales of relative comfort or discomfort. When it is desired to chart the zones of similar degrees of comfort on a map or where any extended comparison is desired, dual references, such as temperature and humidity, must be discarded and a single linear scale adopted. The relative humidity of the atmosphere was accorded unmerited pre-eminence for many years. It is an excellent index of drying conditions for inanimate objects, but its usefulness ceases there. The human body functions as does a wet bulb thermometer in losing heat by evaporation or transpiration in addition to the processes of radiation, conduction and convection. The amount of vapour with its heat content transpired by the lungs and skin is almost wholly regulated by the external pressure exerted by the water vapour in the air against the uniform vapour pressure peculiar to the body temperature, i.e., a vapour pressure equal to the barometric pressure of 1.8 inches of mercury, representing saturation at 98.4°F.

As the result of personal experiment with daily records under uniform conditions, confirmed by the conversion of earlier comfort scales to the same terms, the author determined to use the atmospheric vapour pressure as a measure of comfort. This vapour pressure is the major factor governing transpiration, the greatest source of body heat loss in all Australian latitudes and altitudes. Vapour pressure variations are directly correlated with the other climatic element, temperature, which affects the flow of heat from the body, and, therefore, our personal comfort. A vapour pressure scale is equivalent to a dew point scale, but is more suggestive of the actual physical process involved.

Wind becomes an important factor outdoors, but the absolute humidity is the common predominating element of equal value and effect in both indoor and outdoor climates.

Locations for sanatoria for those undergoing treatment for the lungs have one meteorological element in common in all countries. They may have continental climates, hot and dry with a low relative humidity as in Arizona, or in South Australia at Angorichina Hostel in the Flinders Ranges. Conversely, in higher latitudes or at higher elevations regions of mist and even snow are chosen, and the curative effects ascribed to the cold temperatures. These diametrically opposed conditions, heat and cold, damp and dryness, could scarcely be credited with similar curative powers. The regions chosen have one common factor, a low absolute humidity connoting a low vapour pressure which promotes transpiration.

One remarkable confirmation of the utility and accuracy of the vapour pressure scale was disclosed by testing it against the classification of personal feelings registered by a meteorological observer on the south coast of Queensland. Throughout one winter this observer very consistently entered in his register a personal estimate of the temperature in such terms as "cold," "cool," "mild," "pleasant," "warm," etc. These entries for the six months were arranged in what was considered a correct gradation from the coldest to the warmest. Comparison was then made with (a) the dry bulb temperature, (b) the wet bulb temperature, (c) the relative humidity, and (d) the absolute humidity or vapour pressure. Only in the case of the last element was there an orderly arrangement consistent with the terms representing degrees of personal comfort. Temperature and relative humidity showed an erratic misplacement on the scale, which discounted their value as indicators of the effect of the weather upon the human body. This human hygrometer ceased to function so accurately in the summer months, during which at the time of observation, 9 hours, the vapour pressure was always high, but the range covered in the winter was sufficient to justify the comfort limits already determined.

One important advantage of the vapour pressure criterion over temperature is that the former is almost equal inside and outside a building. Temperature definitions necessitate different specifications for indoor and outdoor climates. The pressures used are calculated on the assumption of a light wind prevailing.

When the atmospheric vapour pressure rises above half an inch transpiration outflow is checked sufficiently to raise the body temperature, causing discomfort and perspiration in the average white man.

If the air temperature be above blood heat, the body suffers a radiation income instead of a loss, and calls for a greater transpiration effort to reduce the internal temperature. This is the normal condition on summer afternoons in the north-west interior of the continent.

When the vapour pressure of the air falls below one-fifth of an inch the transpiration rate is too rapid, because there is too little resistance to the outward pressure from the skin and lungs. With the rapid loss of moisture two different sensations may be experienced according to circumstances. If the air be hot and dry, the mucous membranes of the nose and throat become parched, but if the air temperature is low the sensation of cold is felt owing to the too rapid loss of heat. The map showing the zones of discomfort in Australia was compiled from the mean vapour pressure at 9 a.m. for each month, since the value at that hour is a close approximation to a mean of the 24 hours. Each tenth of an inch of vapour pressure above or below the limits of comfort (.2 to .5 inch) in each month was reckoned as a unit of discomfort. The sums of these units for the twelve months were then reduced to a logarithmic scale, and finally this number was halved to get a convenient number of degrees on the scale of discomfort.

It should be noted that the original summation gives equal value to two-tenths of an inch of vapour in excess for one month, and to one-tenth of an inch in excess for two months. Duration is given equal weight with intensity of stimulus. The introduction of the logarithm effects a convenient reduction of the scale, and provides for the law governing physiological response, by which $\text{Sensation} = \log. \text{Stimulus}$.

The Comfort Map of Australia shows, south of the zero line, that area which on the average does not experience more than two consecutive weeks of uncomfortable weather. Northward, successive zones of increasing discomfort lie between the numbered isopleths. The base map shows the relief of the land surface for comparison with the discomfort zones.

The upper limit of comfort is familiar to all from the fact that perspiration is noticeable with very little exertion. Some people prefer this languid heat, and the novel reason has been advanced that it prevents one from over-exertion, thus exercising a general inhibition, that conserves one's energies.

The lower limit of comfort is most familiar as a too cool condition which prevails in mid-winter on the high lands of south-eastern Australia and on the Tasmanian tablelands. Only towards the centre of the continent does the warm deficiency of moisture become a regular climatic feature. This region is shown on the map as a southward droop of the comfort limit between Central Australia and the north-west coast. During occasional expansions of this area in dry years the adverse effects are felt in the winter months in the inhabited hinterland. Some non-occupational disease, for instance, affects men, women, and children in Broken Hill at intervals of approximately six years, when the vapour pressure (absolute humidity) is lower than usual, and the results are reflected in the death rates of that city.

In Melbourne this lower comfort limit of one-fifth of an inch vapour pressure is occasionally passed on hot, north wind days in the summer. Numerous deaths from infantile diarrhoea during these heat waves have been correlated with the dry heat, i.e., with a low vapour pressure. Infant health warnings are now broadcast when hot, dry weather is expected. Unusually dry weather on the west coast of Tasmania is attended by attacks of typhoid probably associated with poor sanitation, and in the interior of Northern Australia the dry south-east trade wind of winter is sometimes called the "fever wind," since the chill causes a renewal of malarial symptoms.

Another adverse effect to which Dr. H. Lawrence has drawn attention is the incidence of keratosis in the inland districts, particularly among fair people, due apparently to the intensity of ultra-violet insolation, where the humidity is not sufficiently high to act as a protective screen. There is also a strong probability that a considerable amount of nervous irritation and eye trouble originates with the intensity of the light in the drier regions. Conversely, lupus of local origin is now practically unknown. The few cases reported come from Great Britain or the cool, wet districts of New Zealand and Tasmania. A correlation existed between the hot, wet districts, and the maximum incidence of hookworm in tropical Australia.

It is obvious that if excess or deficiency of moisture in the air adversely affects the health it must influence the sensation of personal comfort, even within the less dangerous extremes. The sense of comfort is an index of the amount of energy available for physical or mental pursuits. Physical fitness is associated with the higher temperatures and humidities, and mental ability with the lower, provided they are within the range of comfort. For these reasons it becomes important to find in what regions and in what seasons we may expect excess or deficiency of human energy, both mental and physical. Regions which share the same degree of comfort or discomfort in the annual aggregate lie in the same zones in the map.

In all that area south of the zero line none of the twelve months has an average vapour pressure outside the comfortable limits, i.e., on the average such places have less than a fortnight of discomfort in the year.

The white man's energy should be lowest, according to this map, between Thursday Island and Darwin, and generally lower in the tropics than towards the south coast.

But there is a notable seasonal variation in the degree of comfort, and therefore the amount of energy available, so that the incidence of seasonal occupations might permit of even heavy manual labour by white men in the tropics, provided the greatest exertion were called for in the winter time.

The seasons were compared by calculating the average rate of heat loss in January and July throughout the continent. The heat losses were the equivalent of readings on Leonard Hill's Katathermometer, having been calculated by his formula from the dry bulb and wet bulb thermometer readings. There is, of course, a diurnal fluctuation in these amounts, but the 9 a.m. values are given as a convenient mean for the twenty-four hours. Moreover, Huntington has pointed out in connexion with factory work that the morning conditions affect the tone of the whole day's work.

These heat losses, which are the sums of radiation and transpiration rates, are affected by the elevation of the land. In North Queensland there are, for example, the higher rates, and therefore more pleasant conditions, of the Atherton Plateau. On a map showing mean annual heat losses the 14.5 millicalories isopleth corresponds fairly closely with the limit of comfortable conditions or zero line on the accompanying map.

If the rate is lower than 14.5 millicalories per square cm. per second a person perspires when at rest. In mid-winter the Peninsula, Northern Australia, and North Kimberley only suffer this disability, but in mid-summer Victoria, Tasmania, and the settled areas of South Australia only enjoy immunity.

Taking this rate as a criterion, the manual labourers at Derby (W.A.) and Townsville (Qld.) in July endure conditions similar to labourers in Port Augusta (S.A.) and Eden (N.S.W.) in January. In this respect particular interest attaches to Townsville, which has the largest white urban population within the tropics.

Port Douglas (Qld.) in July resembles Sydney in January. While the tropics present undoubted disadvantages in summer, manual labour in certain seasonal occupations may find favorable climatic conditions

in the winter. The sugar industry, which calls for some of the hardest manual labour in the north, makes the greatest demands for exertion in the more favoured winter months.

In the following table the annual variation of the rate of heat loss is compared for Townsville, Brisbane, Sydney, and Melbourne. The most pleasant conditions prevail during such seasons, as the heat loss is above the critical 14.5 millicalories rate.

RELATIVE RATES OF HEAT LOSS.—KATATHERMOMETER EQUIVALENTS.

Millicalories per sq. cm. per sec.

Station.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Townsville .. Lat. 19° 14' S.	8.8	8.8	9.7	11.0	13.0	14.2	14.4	13.9	12.7	11.0	9.9	9.1
Brisbane .. Lat. 27° 28' S.	11.0	11.2	11.7	13.5	15.5	16.6	17.0	16.6	14.9	13.7	12.5	11.5
Sydney .. Lat. 33° 51' S.	12.8	12.8	13.4	14.9	17.1	18.2	18.5	17.8	16.5	15.4	14.2	13.2
Melbourne .. Lat. 37° 49' S.	14.9	14.8	15.6	16.8	17.9	18.8	19.2	18.6	17.9	17.2	16.4	15.6

The favorable conditions at the ancient centres of western civilization, Athens and Rome, and the modern world metropolis, London, are worthy of note. To the relatively dry conditions at Athens, Hann, the Austrian climatologist, ascribes much of the bodily and mental vigour which made the Greeks the torchbearers of European civilization.

Australian cities do not reach the adverse extremes attained by New York and Chicago every year. Rio de Janeiro, on the tropic, with the largest population in the Southern Hemisphere, is never more than a fortnight within the zone of complete comfort, and at latitude 19°S. Townsville, which has the distinction of the largest white population in the tropics, just reaches in midwinter the favorable conditions of a southern summer.

The data presented show that sub-tropical Australia enjoys a climate favorable practically throughout the year for the development of an energetic race. The tropics experience adverse conditions in midsummer, but the greater part of the area enjoys some respite in the winter, when conditions are equal to those of a southern summer.

Many of the disadvantages of tropical life are disappearing under hygienic control, and much improvement may still be expected.

The disparity between the rates of body heat loss in the north and in the south certainly emphasizes the necessity for a diet adjusted to supply the much lower quantities of heat required in the tropics.

The daily variability of the weather will always be an important factor in favour of the southern States, but the extent of the disadvantage suffered in the tropics is fairly indicated by the degrees of discomfort on the map.

On tropical islands white settlement tends to gravitate to the windward shores since the wind facilitates heat losses in the open air. Away from the steady trades the wind exhibits a diurnal variation of velocity reaching a maximum about the same time as the temperature maximum in the afternoon when the radiation income partly counteracts the effect of the wind. Indoors these changes are less marked but the vapour pressure remains much the same as in the open air.*

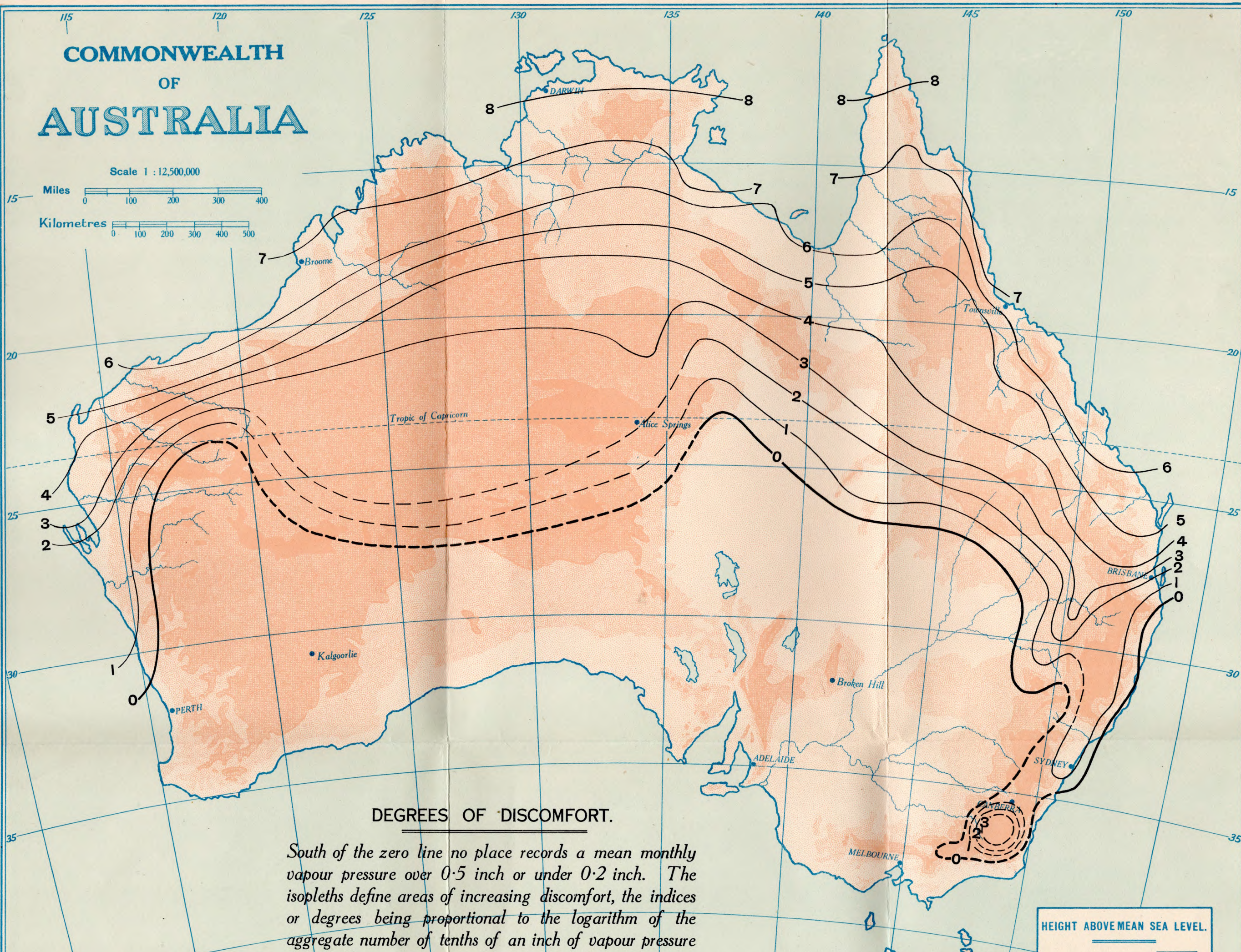
* Much of the above paper appeared under the same authorship as Part 8 of Chapter VIII. of "The Peopling of Australia," the first volume of a series published by the Australian Section of the Institute of Pacific Relations, by whose courtesy it is reproduced.

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Scale 1 : 12,500,000

Miles 0 100 200 300 400

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Department of the Interior,
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